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Bay of Biscay sound scattering layers composition

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Summary: The spatial distribution of zooplankton is generally sampled at coarse vertical and horizontal scales, based on discrete net or video tows. Series of acoustic pelagic surveys yet contain unexplored higher resolution multi-frequency data. Zooplankton and micro-nekton are supposed to contribute to ubiquitous, mesoscale, dense acoustic data and ground-truthing data are scarce. We present such a combined analysis for the Bay of Biscay. Multi-frequency acoustic data were collected in front of the Gironde estuary (Bay of Biscay) using a Simrad EK60 echo-sounder operating at the 18, 38, 70, 120 and 200 kHz frequencies. Ground-truthing data comprised hydrological and plankton data collected at stations using a dropsonde equipped with: CTD, laser granulometer, Laser Optical Particle Counter and an Underwater Video Profiler. Meso-zooplankton and mesopelagic nets were also used to sample a particle size spectrum as large as possible. A joint analysis of acoustic and ground-truthing data by combination of forward and inverse method to assess each station SSL composition is presented here. The forward method appears to be the most relevant to relate the acoustic response to biological samples. It reveals gaps in the biological sampling. The difference between estimated and measured frequency response could be explained by that of gas bubbles not found in the net samples. This approach finally reduces the range of possible hypotheses regarding the nature of organisms that can produce sound scattering layers and suggests that the resonant gaseous scatterers may be fish larvae swimbladders or siphonophores pneumatophores.

The spatial distribution of zooplankton is generally sampled at coarse vertical and horizontal scales, based on discrete net or video tows. Then the samples biological determination is time consuming even with automatic optical methods which still need an expert control. Besides, series of acoustic pelagic surveys yet contain unexplored higher resolution multi-frequency data. Such acoustic information are available continuously over large geographical areas and can be relied to discrete hydro-biological data. Zooplankton and micro-nekton are supposed to contribute to ubiquitous, mesoscale, dense acoustic scattering layers. The multi-frequency responses of those layers guide the determination of their composition. Ground-truthing data are still needed to validate hypotheses but remain scarce. The mixed composition of most layers induces the acoustic responses difficult to interpret. We present here a method aiming to understand the sound scattering layers biological composition for the Bay of Biscay by combining acoustic data and hydro-biological sampling.

Data were collected in the Gironde estuary area during the Ifremer PELGAS survey aiming at monitoring the Bay of Biscay pelagic ecosystem in spring. Multi-frequency acoustic data were continuously recorded using five split-beam Simrad EK60 echo-sounders operating simultaneously at the 18, 38, 70, 120 and 200 kHz frequencies. Ground-truthing data included hydrological and plankton data collected at station located every 10 nautical miles. A dropsonde equipped with: CTD, laser granulometer, Laser Optical Particle Counter and an Underwater Video Profiler was used. Meso-zooplankton (Multinet) and mesopelagic (Middle Isaak Kid, MIK) nets were also used to sample a particle size spectrum as large as possible. Filtered MIK (mesopelagic net) samples (< 2 mm) were digitized by a home-made flow imaging system called TALIM (Meso-zooplankton Imaging Treatment and Analysis). The pictures were subsequently classified into groups defined according to the different types of back-scatterers potentially present in the zone. Organisms abundance and length for each class were used to describe the meso-zooplankton community around each station. Considering the MIK samples micro-nektonic fractions (> 2 mm), biological identification and length measurements were visually performed after a sub-sampling step.

Acoustic data were integrated over sampling units within the spatio-temporal boundaries of the MIK net sampling and multi-frequency responses were calculated. Biological samples identification and acoustic responses have then been relied following two methods. The inverse problem has been performed through an inversion algorithm (Holliday (1977); Lebourges-Dhaussy and Ballé-Béganton (2004)) estimating the abundances and lengths of organisms according to a selected back-scatterer model. Abundance estimations were then compared to the ones observed in the MIK net samples. To perform the forward method, target strength has been calculated for each type of back-scatterer present in the MIK net sample and multiplying by the observed abundance. The estimated frequency response was then compared to the one measured by the echo-sounders.

Correlation analysis between acoustic data and CTD, granulometer, LOPC, UVP profiles or mesozooplanktonic net samples have not been successful so we focused on micro-nektonic net samples to study the sound scattering layer composition.
Shown results are based on the method application to one station of interest located on the continental shelf. MIK net samples biological determination reveals the dominance of large euphausiids with the presence of copepods, siphonophores bracts and nectophores and *Sardina pilchardus* larvae. At the considered station the measured frequency response within the MIK samples boundaries shows a dominant peak at the 38 kHz (-63 kHz) frequency with a particularly low scattering strength at 18 kHz (-85 dB). This particular curve shape show the dominance of gaseous objects of the total scattering strength. The Ye model representing an elongated gaseous sphere back-scattering is chosen to estimate the abundance and length of the dominant back-scatterer. The inversion algorithm estimates the scattering strength of the 38 kHz frequency to be dominated by 1,6 mm long gaseous objects (at 8 ind./m^3). The forward method applied to the MIK sample of the considered station recomposed a frequency response lower than the measured one. The difference between estimated and measured curves highlight the net limits to sample gas-bearing organisms. To explain the missing part in the estimated frequency response, inversion estimations are used. The gap is felt by adding the back-scattering of 2,09 mm long gaseous objects (at 5 ind./m^3). Results of both methods are needed to make up for the net miscatch when gas-bearing organisms are targeted. According to the MIK net samples determination, the organisms able to bear such gas inclusions may be the siphonophores (with their pneumatophore) or fish larvae (with their swimbladder).

The inverse method will detect potentially present gaseous inclusions but as no gas bubble observation has been made, there is no way to make a valid comparison between observed and estimated abundances. The results obtained with the inverse method can be used as hypothesis about the gaseous inclusions diameters but especially reveal a gap in the biological sampling. However, by using the forward method, all the back-scatterers present in the net samples are used to estimate a multi-frequency response including virtual gas bubbles with parameters coming from inversion results. The gap between estimated and calculated frequency response can then be explained. Finally, the combination of both methods can directly show which kind of back-scatterer is missed by the nets used and its length can be estimated. This approach reduces the range of possible hypotheses regarding the nature of organisms that can produce sound scattering layers.

References.
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